

CONTENTS

Foreword	xv
Preface	xix
Contributors	xxiii
1. Stimulus-Responsive Polymers as Intelligent Coatings for Biosensors: Architectures, Response Mechanisms, and Applications	1
<i>Vinalia Tjong, Jianming Zhang, Ashutosh Chilkoti, and Stefan Zauscher</i>	
1.1 Introduction	1
1.2 SRP Architectures for Biosensor Applications	2
1.2.1 Cross-Linked Polymer Networks (Hydrogels)	2
1.2.2 End-Grafted Polymer Chains (Polymer Brushes)	5
1.2.3 Self-Assembled Polyelectrolyte (PEL) Multilayers (LBL Thin Films)	5
1.2.4 Molecularly Imprinted Polymers	6
1.2.5 Hybrid Coatings	6
1.3 Mechanisms of Response	6
1.3.1 Sensing Selectivity	6
1.3.2 Conformational Reorganization of SRP Coatings	7
1.3.2.1 Changes in Osmotic Swelling Pressure	7
1.3.2.2 Changes in Apparent Cross-Link Density	8
1.4 Sensing and Transduction Mechanisms	9
1.4.1 Optical Transduction	9
1.4.1.1 Examples of SRP Sensors That Use Optical Transduction Principles	11
1.4.2 Electrochemical Transduction	14
1.4.2.1 Examples of SRP Sensors That Use Electrochemical Transduction Principles	15
1.4.3 Mechanical Transduction	17
1.4.3.1 Examples of SRP Sensors That Use Mechanical Transduction Principles	18

CONTENTS

1.5	Limitations and Challenges	19
1.5.1	LOD and Sensitivity	19
1.5.2	Selectivity	20
1.5.3	Working Range	20
1.5.4	Response Time	20
1.5.5	Reliability and Long-Term Stability	21
1.6	Conclusion and Outlook	22
	Acknowledgements	22
	References	22
2.	Smart Surfaces for Point-of-Care Diagnostics	31
	<i>Michael A. Nash, Allison L. Golden, John M. Hoffman, James J. Lai, and Patrick S. Stayton</i>	
2.1	Introduction	31
2.1.1	POC Testing Challenges	32
2.2	Standard Methods for Biomarker Purification, Enrichment, and Detection	33
2.3	Smart Reagents for Biomarker Purification and Processing	34
2.3.1	IgG Antibody–pNIPAAm Conjugates	38
2.3.2	Single-Chain Antibody–pNIPAAm Conjugates	39
2.3.3	Nucleotide–pNIPAAm Conjugates	40
2.3.4	Magnetic Nanoparticle (mNP)–pNIPAAm Conjugates	40
2.3.5	Gold Nanoparticle (AuNP)–pNIPAAm Conjugates	42
2.4	Sample-Processing Modules for Smart Conjugate Bioassays	44
2.4.1	Grafting of pNIPAAm from Microchannel Surfaces	45
2.4.2	Grafting of pNIPAAm from Porous Membranes	48
2.4.3	Magnetic Processing Modules	51
2.5	Devices for Use in Smart Conjugate Bioassays	54
2.5.1	Lateral-Flow Immunochromatography Devices	55
2.5.2	Wicking Membrane Flow-Through Devices	56
2.5.3	Polylamine Microfluidic Devices	57
2.5.4	Multilayer PDMS Smart Microfluidic Devices	58
2.6	Conclusions	60
	References	61
3.	Design of Intelligent Surface Modifications and Optimal Liquid Handling for Nanoscale Bioanalytical Sensors	71
	<i>Laurent Feuz, Fredrik Höök, and Erik Reimhult</i>	
3.1	Introduction	71
3.2	Orthogonal Small (Nano)-Scale Surface Modification Using Molecular Self-Assembly	75

3.2.1	Surface Anchor: How to Define and Retain a Molecular Pattern	77
3.2.1.1	Weak Anchors: “Physisorption”	77
3.2.1.2	Strong Anchors: “Chemisorption”	79
3.2.1.3	Weak versus Strong Anchors for Nanoscale Sensors	80
3.2.2	Spacer: How to Suppress Binding	83
3.2.3	Recognizing and Capturing Analytes on an Intelligent Nanostructure	86
3.2.3.1	Antibodies	86
3.2.3.2	Antibody Fragments	87
3.2.3.3	Aptamers	87
3.2.3.4	General Considerations for Recognition Element Immobilization	87
3.3	Alternative Surface Patterning Strategies	89
3.3.1	Lithographic Patterning of Physisorbed Macromolecules	89
3.3.2	Nanoscale Molecular Surface Modification through Printing	90
3.3.3	Nanoscale Molecular Surface Modification through Direct Writing	91
3.3.4	Multivalency and the Intelligent Fluid Biointerface	92
3.3.5	Summary Functionalization of Nanoscale Biosensors	95
3.4	The Challenge of Analyte Transport	95
3.4.1	Convective versus Diffusive Flux (j_C vs. j_D)	98
3.4.1.1	Scenario A ($j_C = 0$)	99
3.4.1.2	Scenario B ($j_C = j_D$)	101
3.4.1.3	Scenario C ($j_C > j_D$)	102
3.4.1.4	Summary of Scenarios A, B, and C	103
3.4.2	Reactive versus Diffusive Flux (j_R vs. j_D)	106
3.4.3	Design and Operation Criteria for Efficient Mass Transport	108
3.5	Concluding Remarks	112
	References	113
4.	Intelligent Surfaces for Field-Effect Transistor-Based Nanobiosensing	123
	<i>Akira Matsumoto, Yuji Miyahara, and Kazunori Kataoka</i>	
4.1	Introduction	123
4.2	FET-Based Biosensors	124
4.2.1	Metal–Insulator–Semiconductor (MIS) Capacitors	124
4.2.2	Principles of bio-FETs	125
4.2.3	Ion-Sensitive Field-Effect Transistors (ISFETs) and Their Direct Coupling with Various Biorecognition Elements as a Conventional Approach to bio-FETs	126

CONTENTS

4.3	Intelligent Surfaces for Signal Transduction and Amplification of bio-FETs	128
4.3.1	CNT-Mediated Signal Transduction	128
4.3.2	SAM-Assisted Detection	129
4.3.3	Stimuli-Responsive Polymer Gel-Based Interfaces for “Debye Length-Free” Detection	130
4.4	New Targets of bio-FETs	132
4.4.1	Carbohydrate Chain Sialic Acid (SA) Detection Using PBA SAM-Modified FETs	132
4.4.2	Scent Detection Using “Beetle/Chip” FETs	134
4.4.3	Aptamer-Modified Biorecognition Surfaces for a Universal Platform of bio-FETs	134
4.5	Future Perspective	135
	References	136
5.	Supported Lipid Bilayers: Intelligent Surfaces for Ion Channel Recordings	141
	<i>Andreas Janshoff and Claudia Steinem</i>	
5.1	Introduction	141
5.2	Supported Lipid Bilayers	142
5.2.1	SSMs on Flat Interfaces	142
5.2.1.1	Lipid Bilayers on Transparent Surfaces	143
5.2.1.2	Lipid Bilayers on Gold Surfaces	143
5.2.1.3	Lipid Bilayers on Silicon	145
5.2.2	SSMs on Porous/Aperture Containing Surfaces	146
5.2.2.1	Lipid Bilayers on Micromachined Apertures	146
5.2.2.2	Lipid Bilayers on Porous Materials	147
5.2.3	Patterning of SSMs	148
5.2.3.1	Patterning of Hybrid SSMs	149
5.2.3.2	Patterning of Nonhybrid SSMs	149
5.3	Characteristics of SSMs	151
5.3.1	Thermomechanical Properties of SSMs	151
5.3.2	Mechanical Stability	154
5.4	Ion Channels in SSMs	157
5.4.1	Carriers	158
5.4.2	Channel-Forming Peptides	158
5.4.3	Channel-Forming Proteins	162
5.5	Future Perspective: Ion Channels in Micropatterned Membranes	163
	References	172

6. Antimicrobial and Anti-Inflammatory Intelligent Surfaces	183
<i>Hans J. Griesser, Heike Hall, Toby A. Jenkins, Stefani S. Griesser, and Krasimir Vasilev</i>	
6.1 Introduction	183
6.2 Antibacterial Strategies	184
6.2.1 The Infection Problem	184
6.2.2 Approaches to Antibacterial Device Surfaces	186
6.2.3 Release of Antimicrobial Compounds from Polymers and Polymeric Coatings	190
6.2.4 Silver-Releasing Coatings	191
6.2.5 Nonfouling Coatings	196
6.2.6 Surface-Grafted Antibacterial Molecules	196
6.3 Bioactive Antibacterial Surfaces	198
6.3.1 Established, Commercially Available Antibiotics	198
6.3.2 Experimental Antibiotics	201
6.4 Stimulus-Responsive Antibacterial Coatings for Wound Dressings	204
6.5 Anti-Inflammatory Surfaces	208
6.5.1 The Inflammatory Response	208
6.5.2 Contact Activation of the Complement System	209
6.5.3 Foreign Body Reaction	211
6.5.4 Anti-inflammatory Medication	212
6.5.5 Local Prevention of the Inflammatory Reaction on Medical Device/Implant Surfaces	215
6.5.5.1 Prevention of Contact Activation of the Complement System	215
6.5.5.2 Prevention of the Foreign Body Reaction by Preventing Macrophage Adhesion and Fusion	216
6.5.5.3 Prevention of Inflammation on Material Surfaces by the Release of NO	217
6.5.5.4 Reduction of the Inflammatory Response by Increasing Hemocompatibility	220
6.6 Conclusions and Outlook	224
References	226
 7. Intelligent Polymer Thin Films and Coatings for Drug Delivery	 243
<i>Alexander N. Zelikin and Brigitte Städler</i>	
7.1 Introduction	243
7.2 Surface-Mediated Drug Delivery	246
7.2.1 Controlled Cell Adhesion and Proliferation	247
7.2.2 Small Cargo	254

7.2.3	Delivery and Presentation of Protein and Peptide Cargo	257
7.2.4	Delivery of Gene Cargo	261
7.3	Drug Delivery Vehicles with Functional Polymer Coatings	268
7.3.1	Core-Shell Particles	268
7.3.2	Polymer Capsules	271
7.4	Concluding Remarks	280
	References	280

8. Micro- and Nanopatterning of Active Biomolecules and Cells **291**

Daniel Aydin, Vera C. Hirschfeld-Warneken, Ilia Louban, and Joachim P. Spatz

8.1	Introduction	291
8.2	Chemical Approaches for Protein Immobilization	291
8.3	Biomolecule Patterning by “Top-Down” Techniques	294
8.3.1	Microcontact Printing (μ CP)	294
8.3.2	Nanoimprint Lithography (NIL)	294
8.3.3	Electron Beam Lithography (EBL)	295
8.3.4	Dip-Pen Nanolithography (DPN)	295
8.4	Biomolecule Nanoarrays by Block Copolymer Nanolithography	296
8.4.1	Block Copolymer Nanolithography	297
8.4.2	Biofunctionalization of Nanostructures	299
8.4.3	Hierarchically Nanostructured Biomolecule Arrays	300
8.4.4	Fabrication of Nanoscale Distance Gradients	302
8.4.5	Soft Polymeric Biomolecule Arrays	303
8.5	Application of Nanostructured Surfaces to Study Cell Adhesion	305
8.5.1	Mimicking the Extracellular Environment	305
8.5.2	Nanoscale Control of Cellular Adhesion	305
8.5.3	Micro-Nanopatterns to Uncouple Local from Global Density	307
8.5.4	Nanoscale Gradients to Induce Cell Polarization and Directed Migration	309
8.5.5	Substrate Elasticity Determines Cell Fate	311
8.6	Conclusion	313
	References	313

9. Responsive Polymer Coatings for Smart Applications in Chromatography, Drug Delivery Systems, and Cell Sheet Engineering	321
<i>Rogério P. Pirraco, Masayuki Yamato, Yoshikatsu Akiyama, Kenichi Nagase, Masamichi Nakayama, Alexandra P. Marques, Rui L. Reis, and Teruo Okano</i>	
9.1 Introduction	321
9.2 Temperature-Responsive Chromatography	322
9.2.1 Hydrophobic Chromatography	322
9.2.2 Ion-Exchange Chromatography	324
9.2.3 Affinity Chromatography	327
9.3 Temperature-Responsive Polymer Micelles	328
9.3.1 Temperature-Responsive Corona	329
9.3.2 Temperature-Responsive Core	332
9.4 Temperature-Responsive Culture Surfaces	333
9.4.1 Temperature-Responsive Culture Dishes	333
9.4.2 Temperature-Responsive Surfaces on Porous Substrates	336
9.4.3 Functionalization of Temperature-Responsive Surfaces	336
9.4.4 Temperature-Responsive Surface Patterning	338
9.5 Cell Sheet Engineering	339
9.5.1 Characterization of Harvested Cell Sheets	339
9.5.2 Applications in Regenerative Medicine	340
9.5.3 Thick Tissue Reconstruction	343
9.6 Conclusions	345
References	346
Index	355